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Title: Fiscal Year (FY) 2017 Activities for the Spent Fuel Nondestructive Assay Project

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Fiscal Year (FY) 2017 Activities for the Spent Fuel Nondestructive Assay Project

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Abstract: The main focus of research in the NA-241 spent fuel nondestructive assay (NDA) project in FY17 has been completing the fabrication and testing of two prototype instruments for upcoming spent fuel measurements at the Clab interim storage facility in Sweden. One is a passive instrument: Differential Die-away Self Interrogation-Passive Neutron Albedo Reactivity (DDSI), and one is an active instrument: Differential Die-Away-Californium Interrogation with Prompt Neutron (DDA). DDSI was fabricated and tested with fresh fuel at Los Alamos National Laboratory in FY15 and FY16, then shipped to Sweden at the beginning of FY17. Research was performed in FY17 to simplify results from the data acquisition system, which is complex because signals from 56 different ^{3}He detectors must be processed using list mode data. The DDA instrument was fabricated at the end of FY16. New high count rate electronics better suited for a spent fuel environment (i.e., KM-200 preamplifiers) were built specifically for this instrument in FY17, and new Tygon tubing to house electrical cables was purchased and installed. Fresh fuel tests using the DDA instrument with numerous configurations of fuel rods containing depleted uranium (DU), low enriched uranium (LEU), and LEU with burnable poisons (Gd) were successfully performed and compared to simulations.[1] Additionally, members of the spent fuel NDA project team travelled to Sweden for a "spent fuel characterization and decay heat" workshop involving simulations of spent fuel and analysis of uncertainties in decay heat calculations.

Introduction

The purpose of the Spent Fuel NDA project is to develop and test integrated technologies to improve nondestructive assay (NDA) measurements of spent nuclear fuel assemblies. These NDA technologies would strengthen the technical toolkit of safeguard inspectors and others to determine the following technical goals more easily and accurately than current state-of-practice:

- Verify initial enrichment, burnup, and cooling time of facility declaration for spent fuel assemblies,
- Detect replaced or missing pins from a given spent fuel assembly to confirm its integrity,
- Estimate plutonium mass and related fissile mass parameters,
- Measure reactivity (multiplication) of each assembly, and
- Estimate decay heat emitted.

As of FY15, the Spent Fuel NDA project field tested three instruments: the passive technology Passive Neutron Albedo Reactivity (PNAR) in Japan, the active technique Californium Interrogation with Prompt Neutron (CIPN), and Self-Integration Neutron Resonance Densitometry (SINRD), the latter two deployed in the Republic of Korea. Two final integrated instruments, the passive DDSI system, and the active (i.e. neutron generator-based) DDA instrument, have been built and are planned for field testing at the Clab interim storage facility in Sweden during FY18.

Differential Die-away Self Interrogation (DDSI)

The DDSI instrument was shipped to Sweden in the latter part of 2016. Researchers went to the Clab facility in Sweden the week of Nov. 7th, 2016 to assemble and test the DDSI instrument. The shipping boxes were unloaded, detector banks were placed in pods, and all pods in the basket responded as expected. Unfortunately, before shipment from Los Alamos, pressure tests on two of the four conduits (with the brand name Glenair) failed, so the instrument was shipped without two conduits, and new conduits were ordered and sent directly to Sweden. Unfortunately, these new Glenair conduits also failed the pressure tests in Sweden. Instead, large diameter/length Tygon tubing has been special-ordered for both the DDSI and DDA instruments, has passed pressure tests in Los Alamos, and will be installed on the DDSI instrument in Sweden in early FY18.

Obtaining data from the list mode data acquisition system and converting them to a usable form (i.e. Rossi-alpha distribution, or RAD) has been a challenge since the inception of the DDSI system. Several different software programs were written to be used in concert to produce the desired form of the data. This proved inefficient during initial testing, and it was determined that it may not be fast enough to handle the large data rates expected from spent fuel. A graduate student was brought onto the project to simplify and speed up the data acquisition and analysis process. He combined several software packages into a single one with a graphical user interface, and made the RAD production process considerably faster. This package has been successfully tested on previously obtained data and will be tested with the DDSI system in Sweden on the early FY18 trip. A journal article on fresh fuel measurements with DDSI was also accepted by IEEE Transactions on Nuclear Science.[2]

Differential Die-Away (DDA)

The frame of the DDA instrument was fabricated during FY16, and the instrument was assembled and tested during FY17. KM200 preamplifier electronics were built to process results from 12 ^{3}He detectors. These were assembled, tested, placed in pods (see Fig. 1), and gain matched successfully in early FY17. Arrangements were made to run the LANL neutron generator in the high bay at TA-35 so that a realistic DDA configuration with fresh fuel rods could be tested. A new enclosure for the neutron generator was built because the generator used at Los Alamos is slightly different that the one that will be used in Sweden. Preliminary tests were performed to calibrate the flux monitor using activation foils. DDA fresh fuel measurements were then performed in mid-March. Results using the neutron generator in both continuous and pulsed mode were obtained, and a number of depleted uranium, low enriched uranium, and Gd rod combinations were measured. A MCNP model of the instrument was also developed, and simulations of results are fairly comparable to measurements.[1,3]

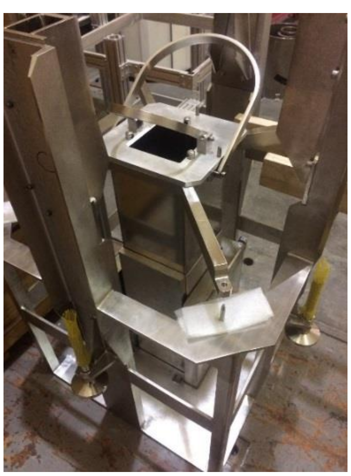

Fig. 1. Picture of DDA instrument frame.

Burnup and Decay Heat Work for the Swedish Collaboration

U.S. researchers put together a workshop on “spent fuel characterization and decay heat” at the SKB Headquarters in Stockholm, Sweden, June 12-16, 2017. The training material was produced and the course taught by another project during the previous month. The workshop was hands-on and focused on application of the SCALE code system capabilities for calculation of decay heat and decay heat uncertainty, isotopic depletion, and radiation source terms. The workshop was attended by 12 staff members from SKB and Vattenfall and was positively received by SKB and other attendees. All presentation material is available upon request, but has not been widely distributed as the files are extremely large. Additionally, a study documenting the use of the Sampler capability in the SCALE code system for evaluating uncertainties in calculated decay heat due to modeling and nuclear data uncertainties was published in Nuclear Engineering and Design.[4]

Remodeling data using the code INDEPTH has also been examined, in particular for the US UNF-ST&DARDS database, which contains design/irradiation information for 140,000 spent fuel assemblies in the U.S. The database will be used to generate inputs for the code TRITON, and the results can be used for decay heat and dose calculations, etc. The work is a proof-of-principle study and offers and opportunities for data mining, for example using results of both gamma emissions and decay heat.

Finally, we have new data from Sweden on some of the SKB-50 assemblies for which we generated isotopics and on which we will perform measurements. There were initial enrichment discrepancies on two of the assemblies, and five of the BWR ones will change significantly because the control blade history is ambiguous and have been re-simulated.

Data Mining

A report on data mining with passive gamma and neutron measurements of the SKB-50 was published.[5]

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